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ABSTRACT

This paper analyzes trends in technology and how they relate to education and then extrapolates these trends in order to predict the future of technology and education. The paper examines how the trends of Moore's Law, the graphical user interface, telecommunications/networks and Metcalfe's Law, the Internet and the World Wide Web, technology fusion, and a changing world economy are redefining the way today's students need to be taught. (Contains 16 references.) (Author/MES)

What Tomorrow May Bring: Trends in Technology and Education

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Abstract: Attempting to predict the future provides targets against which others may compare their thoughts. It might also stimulate efforts that either facilitate or inhibit possible futures implied by the predictions. As technology plays a larger role in education, any predictions concerning the future of education must include an analysis of technological trends. The purpose of this paper is to analyze the trends in technology and how they relate to education, and then to extrapolate these trends in an attempt to predict the future of technology and education. This paper examines how the trends of Moore's Law, Metcalfe's Law, technology fusion, and a changing world economy are redefining the way today's students need to be taught.

Introduction: Education Today

For over a century, education has remained largely unchanged. Classrooms full of students deferring to the wisdom of an all-knowing professor has, is, and many believe, will continue to be the accepted mode of instruction. Despite many technological advances and the introduction of new pedagogical concepts, the majority of today's classrooms continue to utilize this traditional mode. However, as computers and other technologies become easier to use and as the Internet grows, the definition of knowledge is changing. The students of today must now face the fact that as much as 97% of the world's knowledge will be accumulated over their lifetime (Molitor, 1998). As a result, education finds itself in the position of having to recreate itself in order to prepare students to meet these new demands. Unfortunately, it is no secret that education is slow to change, especially in incorporating new technologies.

Education's reluctance to change, especially in incorporating new technologies is described by Jukes and McCain (1997) as *paradigm paralysis*, the delay or limit in our ability to understand and use new technology due to previous experiences. It takes new experiences to replace old ones, and this simply takes time. Unfortunately, education can no longer take the time it wants. The challenge is to prepare the children of today for a world that has yet to be created, for jobs yet to be invented, and for technologies yet undreamed. Trends in technology are creating a future that is arriving faster than education is preparing for it. We must therefore ask what are these trends and how will education adapt to them? To answer this question, the techniques of H.G. Wells, the father of futurist studies, will be used. First we will take a brief look at our past to formulate an understanding of the trends of today. This will be followed by a detailed analysis of these trends. Finally, we will peek into the crystal ball and predict the future of technology and education.

The Trends of Today

Computers and Moore's Law

Since the popularization of the desktop computer in the 1980s, we have become painfully aware of how quickly computers become outdated. A trend of increased power at lower cost that is likely to continue well into the next century and has popularly become known as Moore's Law, after Gordon Moore, the cofounder of Intel Corporation. In 1965 he postulated that technology doubled in processing power approximately every 18 months. The accuracy of Dr. Moore's prediction has proven to be frighteningly accurate. The table below (Tab. 1) illustrates the effects of Moore's Law from 1984 to 1999, with additional assumptions made for memory and costs. In a 1993 speech, Randall Tobias, the Vice Chairman of AT&T, put Moore's Law in perspective when he said, "...if we had had similar gains in automotive technology, today you could buy a Lexus for about $2. It would travel at the speed of sound, and go 600 miles on a thimble of gas. It would be only three inches long...but easy to parallel park!" (pg. 244).

(Assumptions: Every 18 months RAM doubles in size, HD increase 275% in size, CPU speed increases 40%, and cost drops 10%).

Moore's Law	1979	1984	1990	1999
RAM (in Megabytes)	.016	0.128	2	128
HD (in Megabytes)	.128	0.4	24	10,000
CPU (in MHz)	2	10	50	500
Cost	$5,000	$3,900	$2,600	$1,400

Table 1: Moore's Law – 1979 through 1999

The Graphical User Interface

The graphical user interface was first developed by Xerox's Palo Alto Research Center. After a visit to this lab, Steve Jobs, the chairman of Apple Computers, eventually bought the idea and named it Macintosh. "For many, this event has been heralded as the most significant conceptual breakthrough in the history of PCs" (Jukes & McCain, 1997). Other software manufacturers quickly followed Apple's lead, with Microsoft's Windows operating system taking the lead.

During the 1990s, the graphical user interface has allowed the general public to use computers in a variety of ways never imagined possible. The skills in operating a computer have become much like those necessary to play a video game – point there, click the button, and something happens! The generation of video game players, our youth, effectively has become the best audience for computers, yet educators resist using them.

Telecommunications/Networks and Metcalfe's Law

As the power of the computer increases, so do the capabilities of communications media including glass fibers, copper wires, and wireless communication systems. For example, scientists at Fujitsu and other companies have demonstrated the capacity to send data over a single strand of glass the diameter of a human hair at a speed of one trillion bits per second (Thornburg, 1997a). At this rate the entire Library of Congress could be transmitted in seconds (Molitor, 1998), or 70 million simultaneous voice conversations could be sent on a single fiber (Tobias, 1993). Conventional copper wires cannot compete with these rates of transmission, but by using an Asynchronous Digital Subscriber Lines (ADSL) or cable television modems, broadband services of up to ten million bits per second can be achieved. Much like the phenomenon with computer memory, as these speeds increase, the cost of using these services decreases. Take for example the consistent decrease in long distance telephone rates over the last few years; the ability to transmit enormous numbers of calls through one wire has driven prices down substantially.

The combination of better, cheaper computers and increased bandwidth has caused a boon in the network community (i.e. the Internet). Bob Metcalfe, inventor of the Ethernet, suggested that the power of a network increases proportionally by the square of the number of users. Over time this has become known as Metcalfe's Law. Like Moore's Law, Metcalfe's Law has played a major role in shaping the business world, and now it is beginning to affect education. Simply put, Metcalfe's Law states that the more people that are connected to a network, the more powerful that network becomes. As millions connect to the Internet, the Network of networks, the power of sharing information and ideas grows. Education is in the business of sharing information and ideas, making Metcalfe's Law a force that will play a major role in shaping the institution in the years ahead.

Internet and the Web

The merging of Moore's Law, Metcalfe's Law, and easy-to-use graphical interfaces form the foundation of the communication revolution we are now experiencing. The International Data Corporation (IDC) forecasts that 320 million people will be able to access the World Wide Web by 2002. In 1997, 78 million devices connected to the Web; by 2002 this number will increase to 515 million (WISTA, 1998). In 1996, the U.S. Postal Service delivered an astonishing 185 billion pieces of first class mail, yet in that same year the Internet handled about one trillion e-mail messages. Federal Communications Committee Chairman Reed Hunt has said, "The communication age is connected to the greatest revolution in the history of education since the invention of the printing press" (in Thourburg, 1997).

Technology Fusion

Another event that will likely have a significant impact on education is technology fusion. Twenty years ago we saw sharp distinctions between computers, photos, publishing, TV/video, and telecommunications. Now the distinctions between these media are blurring (see Fig. 1 below). In a few more years there will be virtually no distinction between them (Jukes & McCain, 1997) (Lane & Portway, No Date). We are already seeing the manufacturing of computers that can perform all of the functions that not long ago needed separate devices. The Education Coalition (TEC) considers the merger of computing, television, printing and telecommunications as the most significant trend in education and technology. "Bringing them together results in the whole having greater impact than each individual part..." (Lane & Portway).

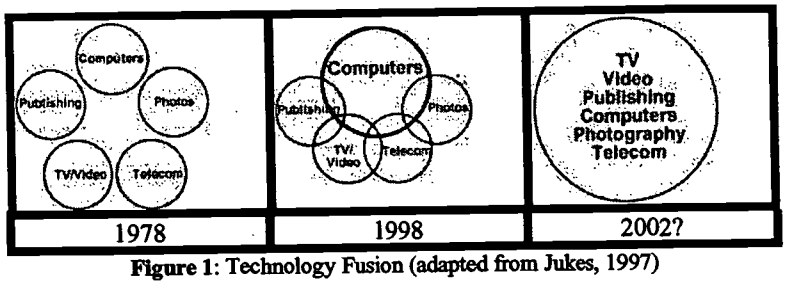

Figure 1: Technology Fusion (adapted from Jukes, 1997)

Economy

If education is responsible for preparing its students to be contributing members to the world economy (it is the opinion of the author that this *is* a responsibility of education), then we must consider what type of an economy these students will be entering. An October, 1998 report published by the World Information Technology and Service Alliance concluded that spending on information and communications technology (ICT) is a critically important element of the worldwide economy. The report presented the broadest view of current levels of customer spending on information technology and communications ever assembled. Below are some of the study's findings (WISTA, 1998):

- Information and communications technology (ICT) was responsible for $1.8 trillion in spending in 1997.
- In 1997, ICT spending was nearly 40% larger than in 1992.
- ICT spending is growing 27% faster than the overall worldwide Gross Domestic Product.
- Spending on ICT is a key accelerator, catalyst, and multiplier of a wide variety of social and economic measures, including company and job growth.
- An average of 7,200 new tax-paying ICT companies have been added in the United States during each of the last five years.

With the world economy so intricately tied to information and communications technologies, the careers of today and tomorrow are directly related to these technologies. The Thornburg Center recently conducted a study of the 54 jobs identified by the U.S. Bureau of Labor Statistics as having the highest numerical growth between now and the year 2005. Of the 54 jobs, 46 required technological fluency, and none of the remaining eight paid more than double minimum wage (Thorburg, 1997a). The lack of technologically fluent workers is already a problem. The Information Technology Association of America has warned that one out of ten jobs requiring information technology skills is going unfilled (in Thornburg, 1997a). Clearly, our educational system is failing to adequately prepare technologically fluent workers, so we must ask what does education need to do to address this problem?

The Role of Education

Being a Webmaster is one of today's hottest careers, yet five or six years ago Webmasters did not even exist. This is an example of how education must consider preparing students for jobs that have yet to be created. Alan Greenspan, the Chairman of the Federal Reserve Board, recently said (1997), "One of the most central dynamic forces [in the economy] is the accelerated expansion of computer and telecommunications technologies...clearly our educational institutions will continue to play an important role in preparing workers to meet these demands" (pg. 98). He also stated, "workers are facing the

likelihood that they will need retooling during their careers...education is increasingly becoming a lifelong activity" (pg. 100). To prepare students to be lifelong learners requires a new approach to teaching; one in which students learn how to learn.

Much of the failure to utilize technology in education today is, as Thornburg puts it, "the assumption that content [is] king...in a world of rapid information growth, it is context that matters...context is king" (in Thorburg, 1997b, pg. 5). Rather than having students learn facts "just in case" they might need them someday, educators should promote "just in time" learning – collaborative learning environments where groups of students find solutions to real-world scenarios. The 1995 Congressional Office of Technology Assessment report entitled Teachers & Technology: Making the Connection, encourages this type of teaching and explained how technology facilitates it (OTA, 1995, pg. 1-2):

> "Using technology can change the way teachers teach. Some teachers use technology in 'teacher-centered' ways...On the other hand, some teachers use technology to support more student-centered approaches to instruction, so that students can conduct their own scientific inquiries and engage in collaborative activities while the teacher assumes the role of facilitator or coach."

Since the large-scale induction of computers into America's schools in the early 1980s, there has been reluctance of educators to implement them. Teachers can hardly be blamed for this reluctance. A major barrier has been a lack of a universal agreement on how teachers should be prepared to use the technology (Willis & Mehlinger, 1996). This is not cause to write off the personal computer for classroom use. In reference to preparing pre- and in-service teachers, Bull and Cooper (1997) believe, "it is important to be realistic about the time frame that will be required to accomplish this [integration of technology] in the depth that may be eventually desired" (pg. 101).

Unfortunately, education is moving along at a snail's pace, while the world outside is speeding by at a supersonic rate. According to Fulton (1989, pg. 12), "Classrooms of today resemble their ancestors of 50 and 100 years ago much more closely than do today's hospital operating rooms, business offices, manufacturing plants, or scientific labs." If you put a doctor of 100 years ago in today's operating room, she would be lost, yet if you placed a teacher of 100 years ago into one of today's classrooms she wouldn't skip a beat. Jack Welch, the CEO of General Electric and an expert on institutional change believes that when the rate of change inside an institution is less than the rate of change outside, the end of that institution is imminent. Does this mean that the end is in sight for education? The answer is YES, if your asking if it means the end of education as we know it today. Let us take a peek at what the future might look like.

The Future

Future Technologies

If one lesson can be learned from our past it is to NOT put limits on what technology might someday produce. Assuming that ANYTHING is possible might be the best assumption. For example, consider what happens when we begin to extrapolate Moore's Law 10 and 20 years into the future (see Tab. 2 below):

Moore's Law	1979	1984	1990	1999	2009	2020
RAM (in Megabytes)	.016	0.128	2	128	17,000	2,000,000
HD (in Megabytes)	.128	0.40	23	10,000	12,000,000	14,000,000,000
CPU (in MHz)	2	10	51	500	5,500	75,000
Cost	$5,000	$3,900	$2,600	$1,400	$670	$320

Table 2 - Moore's Law Extrapolated

While Gordon Moore believes that his Law will someday hit a wall, studies have shown that limitations with existing technology might not be reached for nearly twenty years. It does seem likely that we can assume growth to continue at current rates for several years to come. At these rates, by the time today's first and second graders graduate from high school they will be using a computer that has 17,000

Megabytes of RAM, a HD of 12,000,000 Megabytes, a CPU speed of 5,500 Megahertz, and at a cost of less than $700. Extrapolating further is even more staggering.

It is difficult to imagine what a computer this powerful will be capable of. Adding the effects of Metcalfe's Law and technology fusion should lead us to believe that we will have an increased reliance on a Global Digital Network, capable of sending and receiving any form of digital communication to and from anywhere in the world at any time. A global economy reliant on these emerging technologies is evidenced by current statistics. Still, we must ask what else is possible?

In the very near future we will likely have a keyboardless computer. Voice software is already proving to be effective in its implementation and it seems only a matter of years before the keyboard will be removed from many if not most computer environments. Taking this one step farther, voice translation technologies will allow for nearly instantaneous communication with people of different languages (Molitor, 1998). The business and educational implications are staggering. For example, what if American students could instantly communicate with Chinese students? Would this change education?

Computers are shrinking in size and are now wearable. For under $5,000 Xybernaut sells a powerful speech-activated computer. Also possible are body-implant transceivers, all connected to the Global Digital Network, or medical breakthroughs such as video lens implants, which are already allowing individuals who were once blind to regain partial sight! For any Star Trek fans reading this paper, it might sound like we are slowly turning into the Borg. This idea might seem ludicrous, but the idea of students walking into class with Sony Walkmans, pagers, and cell phones was recently considered ludicrous as well. The technology might someday make unbelievable things possible. It is therefore important for teachers to work closely with technology designers "to create a world that celebrates and promotes humanity through the judicious use of technology" (Graham, 1997, pg. 14).

One must keep in mind that there are countless ways technology might develop during the next several decades. Knowing exactly what these developments will be or where they will lead is not only impossible, it is unimportant. It is the recognition of what is possible that educators must consider. Social implications could possibly be the hardest of all to predict, yet it will be education that many will look to in dealing with these implications. Adequately preparing for these implications will only occur if we look ahead, which ultimately requires us to ask, what do members of the educational community see when they look ahead?

The Future of Education

Gentry and Csete have stated, "educators are slow to recognize the need to develop a curriculum that will prepare the workforce for the demands they will face" (1990, pg. 25). Some would argue that change in education will continue to be a dream unrealized well into the new millennium, but many opinions run contrary to this argument. In 1996, the American Association of School Administrators (AASA) brought together 55 advisors from various fields, including education, business, government, psychology, sociology, anthropology, and demography to study the future of education. A short summary of these findings is (Ulchida, 1996):

- Students need to be skilled in accessing the vast array of information available through advanced technology and be able to process the information.
- Students must know how to use computers and be familiar with various types of technology.
- Schools must incorporate "marketplace" technologies and ensure that new and emerging technologies are incorporated into the school program.

A consistent point brought up by most futurists is the need to provide education to both children and adults. The Special Libraries Association (SLA) believes that schools will become around-the-clock facilities. The academic day will stretch to seven hours for children; adults will work a 32-hour week and prepare for their next job in the remaining hours. A few of the major points brought forward by the SLA are (Cetrone & Davies, 1994):

- The driving force behind educational reform will come from the new information economy's call for technologically fluent workers.
- The government will place more emphasis on the outcomes of public education (for example, America 2000).

- Improved pedagogy will revolutionize learning; learning environments will become less important as individuals will learn more on their own.
- Computer-supported approaches to learning will allow for more content-specific material to be learned.

Gentry and Csete (1990) have also written that pressures from business, industry, and government will "force the educational establishment to better prepare graduates for the workplace" (pg. 27). Several of the points they mentioned were:

- Increased access to electronically delivered instruction will provide new channels of instruction developed independently of traditional educational systems.
- Artificial intelligence will have an increased role in education; as technology becomes easier to use, more educators will become adopters.
- Technology-capable students will demand the adoption of technology; independent learning skills (lifelong learning) will need to be supported.
- People conforming to technology will shift to technology fitting the diversity of the people using it.

Jukes and McCain (1997) of the Thornburg Center offer insight into the future of technology and education. Both see education's role as being similar to that of a quarterback on a football team: "A quarterback must be a futurist – throwing the ball not to where the receiver is, but to where the receiver is going to be. It's much the same with technology. We need to be looking ahead 3, 4, even 5 generations down the road" (pg. 9). Jukes, McCain, and David Thornburg advocate a new educational paradigm that shifts curriculum from content-based to process-based. Their message is that educators need to change their mindset quickly, "or the market will find its educational experiences elsewhere" (Jukes & McCain, 1997, pg. 10). These experiences found elsewhere are already evidenced in increased home school numbers and support for school vouchers.

Conclusion: The Author's Views

Experts from all fields, including education, business, and government agree that we have moved into the information age. As much as 97% of the world's knowledge will be accumulated over one person's lifetime. Against statistics like this, teaching students a host of facts "just in case" they need them later on in life is a fruitless effort. The ability to find and use facts as they are needed becomes the skill that will enable students to become lifelong learners. Consequently, the teacher's role shifts from that of the transmitter of facts, to a facilitator, coaching students in how to find and use facts specific to a particular context. The role of education is no longer to provide educational opportunities through early adulthood, but to provide the scaffolding necessary to support individuals and families from all walks of life, throughout their entire lives. In order to prevent a further widening between the upper and lower classes, it will become increasingly important for educational institutions to provide this support by providing weeknight and weekend adult classes focused on emerging technologies.

Very soon we can look for interactive video technologies to allow parents to play a more active role in their child's education (e.g. watching a class presentation via online video). Students will utilize wireless, handheld, voice-activated computers that look similar to today's video game controllers. These devices will be connected to a Global Digital Network (Internet) and will be capable of displaying video and audio as well as text-based materials. Schools that actively pursue such avenues will be in great demand. School days will grow to seven hours in length to provide more instruction and to meet the needs of dual income families. As more states pass school voucher initiatives, a greater dependency upon private education and home schooling will result.

As mentioned earlier, knowing exactly what happens in our future is not important. It is important that educators have a sense of where the world is headed. Only then will they be able to adequately prepare current and future students to thrive in this ever-changing world. We must always keep in mind that a good driver doesn't watch the car's hood while they are motoring down the road. Instead, a good driver carefully watches the road ahead, looking for the obstacles and challenges that lie before them. It is time that education quit watching its hood and start looking at the road ahead.

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